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A STUDY OF THE SCATTERING
OF SOUND WAVES IN FLUIDS
PART II - INFLUENCE OF SUBMARINE HULLS
ON SOUND INTENSITY MEASUREMENTS
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Technical Report No. 680(00)-3
June 10, 1953

The research reported in this document
was done under ONR Contract No. 680(00)
between the Office of Naval Research
and the Magnolia Petroleum Company.

Magnolia Petroleum Company
Field Research Laboratories
Dallas, Texas

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Date: 8/5/53

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ABSTRACT

A theoretical estimate of the influence of a submarine hull
on the direction of the total sound intensity in the vicinity of the hull
is given. It is concluded that under typical operating conditions an
intensity detector located perpendicular to and several feet from the deck
of a submarine will indicate within reasonable limits the true direction
of the incident sound wave.

A STUDY OF THE SCATTERING OF SOUND WAVES IN FLUIDS
PART II - INFLUENCE OF SUBMARINE HULLS ON SOUND INTENSITY MEASUREMENTS

Sound intensity measurements made in the vicinity of a submarine hull are influenced by the presence of the hull. Under certain conditions the direction of the average total sound intensity measured by the detector may not coincide exactly with the true direction of the incoming sound field. The analysis presented in this report shows that under typical operating conditions an intensity detector located perpendicular to and several feet from the deck of a submarine hull will indicate within reasonable limits the true direction of the source of sound.

If an accurate determination of the direction of the source is desired, it is necessary to determine to what extent the direction of the total sound intensity differs from that of the incident sound intensity. In order to obtain a theoretical estimate of the influence of the hull on the direction of the total sound intensity, the scattering of a plane wave by a spherical bubble characterized by a perfect pressure release surface has been examined. This problem is amenable to mathematical treatment and is discussed in detail in Part I. It is realized that a submarine hull is neither spherical nor a perfect pressure release surface; however, results obtained from an analysis of this limiting case should yield a reasonable estimate of the maximum disturbance encountered by an actual submarine hull.

The problem treated in Part I is that of a plane wave scattered by a spherical bubble immersed in an infinite homogeneous perfect fluid. Expressions for the magnitude and direction of the average total intensity of the entire sound field very close to the bubble are obtained. Also,

the deviation between the direction of the average total sound intensity
produced by a plane wave incident upon a spherical bubble and the average
intensity of the same plane wave with no bubble present is determined.
This quantity, which is called the Intensity Deviation Angle, gives the
angular deviation between the direction determined by the intensity
measuring device and the true direction of the sound field. Knowledge
of the Intensity Deviation Angle makes it possible to determine whether
sound intensity measurements are seriously altered by the presence of a
submarine hull.

In order to obtain some idea as to the influence of a spherical
bubble on the average total intensity, values of $2\pi a/\lambda = 0.1$ and r/a
= 2 have been taken as representative of a submarine in a sound field of
long wavelength. These values correspond approximately to a bubble diam-
eter of 15 feet and a wavelength of 500 feet. Figure 4 of Part I is a
plot of the Intensity Deviation Angle as a function of the polar angle θ.
The maximum value of the Intensity Deviation Angle is 23.5 degrees and
occurs when θ = 146 and 326 degrees. The minimum value of the Intensity
Deviation Angle is -23.5 degrees and occurs when θ = 34 and 214 degrees.
It should be pointed out, however, that these values are extreme limits
that are never encountered in practice. Under typical operating conditions,
for example, the detector will probably be mounted several feet above
the deck of a submarine. This position of the detector on the submarine
corresponds to a value of θ equal to 90 degrees in the spherical bubble
problem. If the direction of the incident intensity does not make an

angle of more than 5 degrees with the horizontal plane of the submarine, it is easily shown that the Intensity Deviation Angle does not exceed 3 degrees. Therefore, if the intensity detector is to be used by a submarine as an early warning device to indicate the presence of and general direction toward a source of sound, the variation of the Intensity Deviation Angle under typical operating conditions will be small. Figure 5 of Part I is a polar plot of the ratio of the average total sound intensity to the average intensity of the incident plane wave. Note that the arrows shown on the polar diagram indicate the direction of the total sound intensity vector with respect to the polar axis at the point $(2a, \theta)$. The value of $|\vec{T}_T|/T_o$ 7.5 feet away from the surface of the bubble in the backward direction along the polar axis is 0.185. The total sound intensity is zero on the surface of the bubble and approaches the incident sound intensity as the distance from the bubble increases.

In addition to the bubble problem just discussed, a better approximation to a submarine hull would be a prolate spheroid characterized by a surface impedance. The introduction of an impedance would make it possible to allow for the acoustical properties of the submarine hull. By varying the angle the incident plane wave makes with the major axis of the spheroid, it would be possible to obtain some idea as to the effect produced when a sound source changes its angular position with respect to the longitudinal axis of the submarine. It is planned to study this problem at some future date.